Distortion Limits of Pre-adjusted Orthodontic Bracket using Finite Element Analysis

Jakirhussain Shaik[1], T.V.S.R.K Prasad[2]
[1]M.Tech(CAD/CAM) Student, Department of Mechanical Engineering, Nimra College of Engineering & Technology.
[2]Professor & HOD of Mechanical Engineering, Department of Mechanical Engineering, Nimra College of Engineering & Technology, Vijayawada, AP, INDIA

ABSTRACT

Since number of adults seeking orthodontic treatment has been increasing. The preadjusted orthodontic bracket is most widely used in dentistry because of its preadjusted angulation in slot dimensions, which is helpful for translating the teeth with less force compared to normal conventional bracket which do not have slot inclination.

The objective of this study is to model a pre-adjusted maxillary right central incisor orthodontic bracket the dimensions used in this project are taken from a hospital regarding the orthodontic bracket. Then it was modeled using CATIA. The meshing and analysis of the bracket is to be done by using Ansys to find the distortion limits and stress distribution pattern of the different bracket materials by providing loads to the bracket of varying arch wire sizes. The torque and tipping couple force is considered to analyze the deformation and stresses of preadjusted orthodontic bracket.

Keywords: *Ansys, arch wire, bracket, Catia, preadjusted angulation, torque force & tipping force.*

I. INTRODUCTION

Orthodontics is the first specialty of dentistry that is concerned with the study and treatment of malocclusions (improper bites), which may be a result of tooth irregularity, disproportionate jaw relationships, or both. Orthodontic treatment can focus on dental displacement only, or can deal with the control and modification of facial growth. In the latter case it is better defined as "dent facial orthopedics". Orthodontic treatment can be carried out for purely aesthetic reasons with regards to improving the general appearance of patients' teeth. There are orthodontists who work on reconstructing the entire face rather than focusing exclusively on teeth.

Fig.1 shows the various components of the orthodontic bracket system. When brackets put pressure on ones teeth, the periodontal membrane stretches on one side and is compressed on the other. This movement needs to be done slowly otherwise the patient risks losing his or her teeth. This is why brackets are commonly worn for approximately two and a half years and adjustments are only made every three or four weeks. This process loosens the tooth and then new bone grows in to support the tooth in its new position which is technically called bone remodeling.

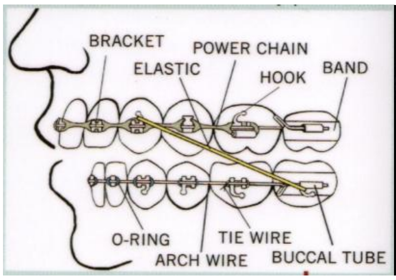


Fig.1 components of brackets

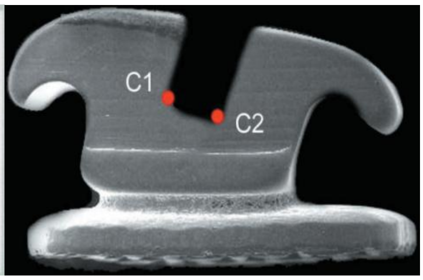


Fig.2 Preadjusted bracket

II. PREADJUSTED BRACKET

In preadjusted bracket the slot size is given with some inclination angle as shown in fig.2, this is helpful in translating the tooth position with less applied force on the arch wire.

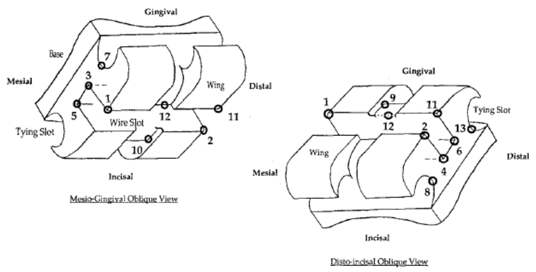


Fig.3 Positions of the orthodontic bracket

III. PROPOSAL OF THE PRESENT WORK

Orthodontic bracket involves various mechanical forces, in general dentist apply forces to activate the archwire. In this work, preadjusted orthodontic bracket (Ormco roth) alone is considered to study the distortion limits and stress pattern of ceramic , stainless steel and titanium bracket for **torque and tipping couple force** using finite element method.

IV. MODELING OF THE BRACKET USING CATIA

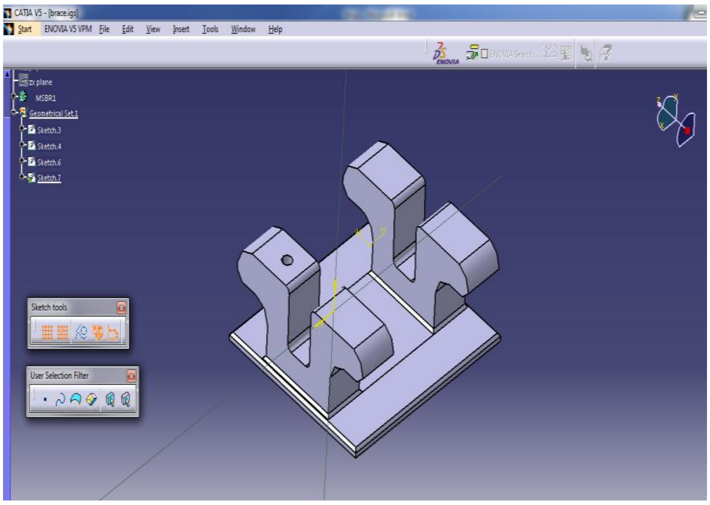


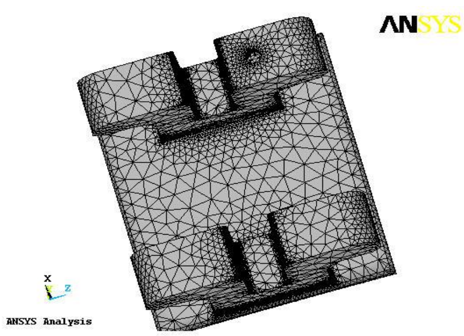
Figure 3.9: 3D Model of the bracket

V. ANALYSIS OF THE BRACKET USING ANSYS

- Material properties of bracket model

MATERIAL	MATERIAL PROPERTIES		
	YOUNGS MODULUS(MPA)	DENSITY (KG/MM^3)	POISSON'S RATIO
CERAMIC	3.7921e^{05}	3.8752e^{-06}	0.29
STAINLESS STEEL	2.1000e^{05}	7.7500e^{-06}	0.29
TITANIUM	1.1000e^{05}	4.5070e^{-06}	0.33

Table.1 Material properties of bracket model



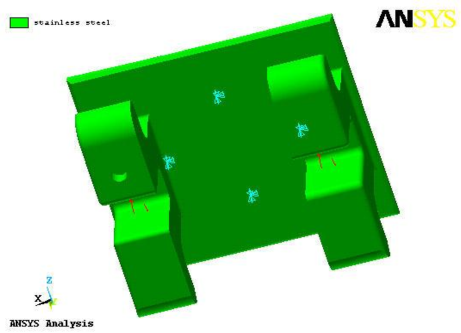
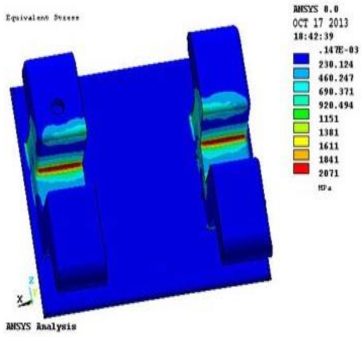


Fig.4 Meshed model of bracket **Fig.5** Orthodontic bracket with boundary conditions and loads

1. Results & discussion

a. Analysis of stress of the orthodontic bracket for the torque force

- The stresses obtained when torque force (pressure) applied to the ceramic bracket with no additional torque for archwire 0.4826✕0.6609 mm is shown in below fig.6
- The stresses obtained when torque force (pressure) applied to the ceramic bracket with additional torque of 20° for archwire 0.4826✕0.6609 mm is shown in below fig.7



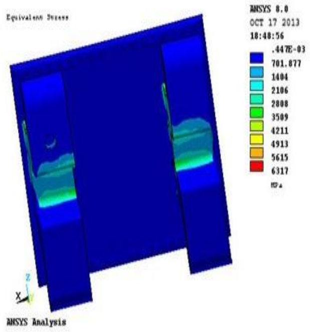
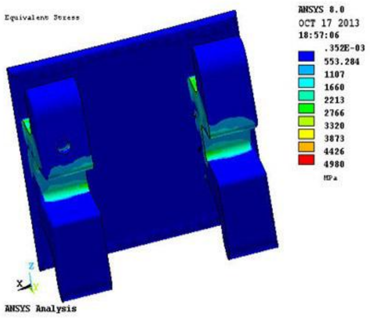


Fig.6 Stresses in the ceramic bracket for the pressure of 816Mpa   Fig.7 Stresses in the ceramic bracket for the pressure of 2542.711Mpa

- The stresses obtained when torque force (pressure) applied to the ceramic bracket with no additional torque for arch wire 0.4572✕0.6096 mm is shown in below fig 8.
- The stresses obtained when torque force (pressure) applied to the ceramic bracket with 20° additional torque for arch wire 0.4572✕0.6096 mm is shown in below fig 9.



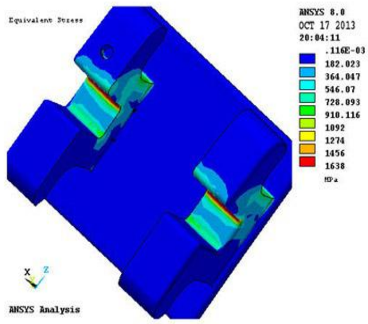


Fig.9 Stresses in the ceramic bracket for the pressure of 1961.9Mpa   **Fig.8** Stresses in the ceramic bracket for the pressure of 645.44Mpa

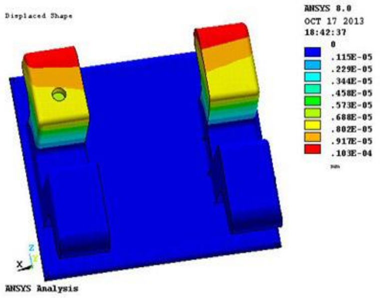
- **Stress results of the orthodontic bracket**

SLNO	SPECIFICATION	Max. Stress(Mpa) acting on Bracket with Material		
		CERAMIC	STAINLESS STEEL	TITANIUM
1	Archwire size (0.4826*0.6604)mm without additional torque	2071	1173	583.014
2	Archwire size (0.4826*0.6604)mm with 20° additional torque	6317	3575	1872
3	Archwire size (0.4572*0.6096)mm Without additional torque	1638	926.671	485.084
4	Archwire size (0.4572*0.6096)mm with 20° additional torque	4980	2824	1479

Table.2 The stresses acting on the bracket for calculated torque force

b. Analysis of Displacement of the orthodontic bracket for the torque force

- The displacement obtained when torque force (pressure) applied to the ceramic bracket with no additional torque for archwire 0.4826✕0.6609 mm is giving below fig 10
- The displacement obtained when torque force (pressure) applied to the ceramic bracket with additional force of 20° for archwire 0.4826✕0.6609 mm is giving below fig 11



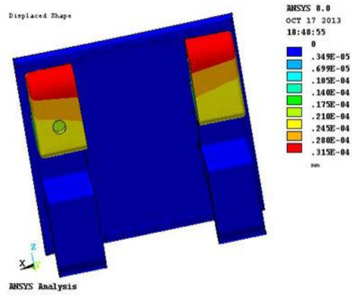
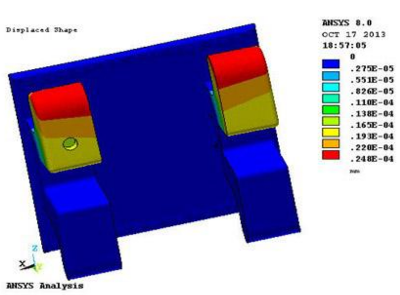


Fig.10 Displacements in the ceramic bracket for the pressure of 816Mpa **Fig.11** Displacement in the ceramic bracket for the pressure of 2542.711Mpa

- ❖ The displacement obtained when torque pressure applied to the ceramic bracket with no additional torque for arch wire 0.4572×0.6096 is giving below fig 12
- ❖ The displacement obtained when torque force (pressure) applied to the ceramic bracket with 20° additional torque for arch wire 0.4572×0.6096 mm is giving below fig 13



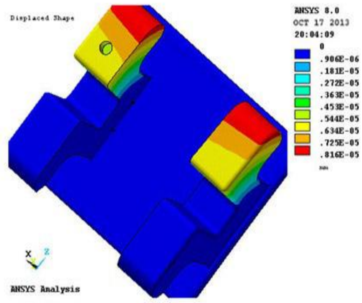


Fig.13 Displacement in the ceramic bracket for the pressure of 1961.9Mpa Fig.12 Displacement in the ceramic bracket for the pressure of 645.44Mpa

➢ Displacement results of the bracket for torque

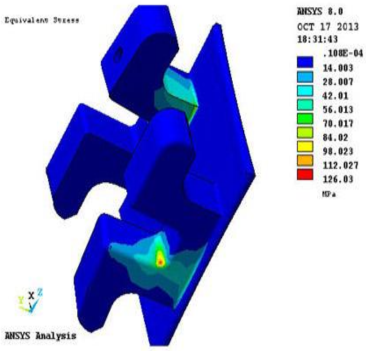
Table.3 shows the displacement results of the different bracket materials with different archwire sizes. It shows that the titanium bracket of archwire size (0.4826*0.6604) mm is having more displacement compared to other bracket materials

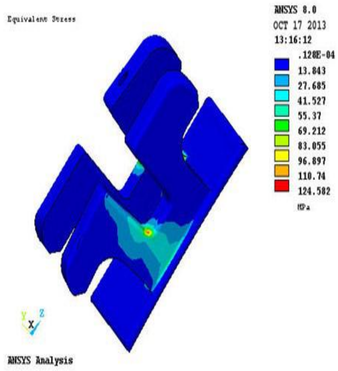
SLNO	SPECIFICATION	Max. Displacement in mm acting on Bracket with Material		
		CERAMIC	STAINLESS STEEL	TITANIUM
1	Archwire size (0.4826*0.6604)mm without additional torque	$0.103e^{-04}$	$0.101e^{-04}$	$0.994e^{-05}$
2	Archwire size (0.4826*0.6604)mm with 20° additional torque	$0.315e^{-04}$	$0.321e^{-04}$	$0.346e^{-04}$
3	Archwire size (0.4572*0.6096)mm Without additional torque	$0.816e^{-05}$	$0.833e^{-05}$	$0.827e^{-05}$
4	Archwire size (0.4572*0.6096)mm with 20° additional torque	$0.248e^{-04}$	$0.254e^{-04}$	$0.252e^{-04}$

Table.3 Displacement results on the bracket

c. Analysis of stress of the orthodontic bracket for the tipping force

- ❖ The stresses obtained when tipping force applied to the ceramic bracket is given below fig.14
- ❖ The stresses obtained when tipping force applied to the stainless steel bracket is given belowfig.15
- ❖ The stresses obtained when tipping force applied to the titanium bracket is given below fig.16





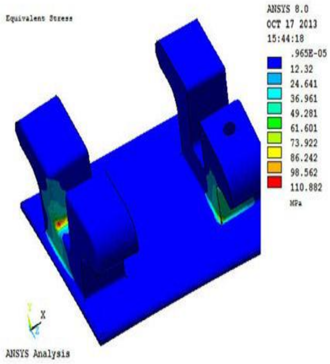


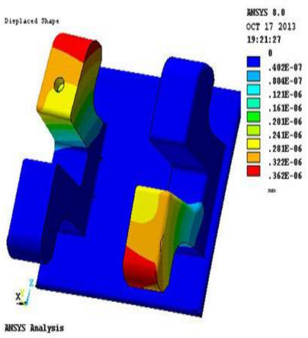
Fig.14 Stress in the ceramic bracket for the pressure of 37.100 Mpa, **Fig.15** Stress in the stainless steel bracket for the pressure of 37.100Mpa, **Fig.16** Stress in the titanium bracket for the pressure of 37.100Mpa

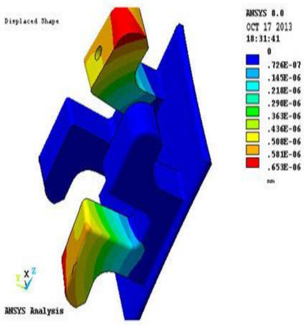
SLNO	TIPPING (PRESSURE)	Max. Stress(Mpa) acting on Bracket with Material		
		CERAMIC	**STAINLESS STEEL**	**TITANIUM**
1	37.100	126.03	124.4	110.882

Table 5.6: Maximum Stresses acting on the bracket for tipping

The above table shows that in tipping force ceramic is having more stress value compared to stainless steel and titanium bracket.

- **Displacement of the orthodontic bracket for tipping force**
- The displacement obtained when tipping force applied to ceramic bracket is given below fig.17
- The displacement obtained when tipping force applied to the stainless steel bracket is given below fig.18
- The displacement obtained when tipping force (pressure) applied to the titanium bracket is given below fig.19





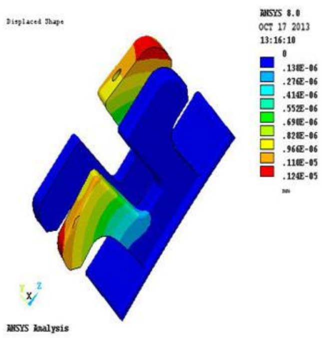


Fig.17 Displacement in the ceramic bracket for the pressure of 37.100Mpa **Fig.18** Displacement in the stainless steel bracket for the pressure of 37.100Mpa, **Fig.19** Displacement in the titanium bracket for the pressure of 7.100Mpa

SLNO	TIPPING (PRESSURE)	Max. Displacement (mm) acting on Bracket with Material		
		CERAMIC	STAINLESS STEEL	TITANIUM
1	37.100	$0.361e^{-06}$	$0.653e^{-06}$	$0.124e^{-05}$

Table 5.7: Maximum displacement acting on the bracket for tipping force

The above table shows that the titanium is having more displacement compared to stainless steel and ceramic when tipping force is applied

VI. CONCLUSION

- The stress distribution pattern of the bracket showed that the stresses tended to concentrate at or near points of application of force.
- Stresses were concentrated at corners, edges, and other areas of abrupt change in the shape of the bracket.
- The deformation of the ceramic bracket is less compared to stainless steel bracket and titanium bracket.
- From the results if the additional torque is introduced to the brackets we observe that the stress and deformation values are higher than without additional torque.
- For the application of torque force the maximum stress is in Distogingival base wire slot point.
- For the application of torque force the maximum displacement is found in Mesiogingival outer wire slot point.
- For the application of tipping force the maximum stress is in Mesiogingival base wire slot point.
- For the application of tipping force the maximum displacement is found in Mesiogingival outer wire slot point.

VII. FUTURE SCOPE

In future the finite element analysis can be done to find the distortion and stress analysis of the orthodontic bracket by considering the periodontal ligament, bone, tooth alone with the orthodontic bracket.

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